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(54) Determining sleep states

(57) A system for determining the sleep state of a person provides indexes representing the variation of a biological signal such as pulse or respiration rate on the basis of first variation amount denoting a trend with time of the biological signal from the start of measurement and second variation amount denoting the temporal variation of the biological signal, and discriminates different sleep states on the basis of the distribution density of the variation indexes exceeding a predetermined threshold, whereby NREM and REM sleep periods in particular can be reliably discriminated. This provides sleep information which enables an awakening stimulus to be generated shortly after termination of REM sleep to ensure a comfortable awakening.

Fig.1

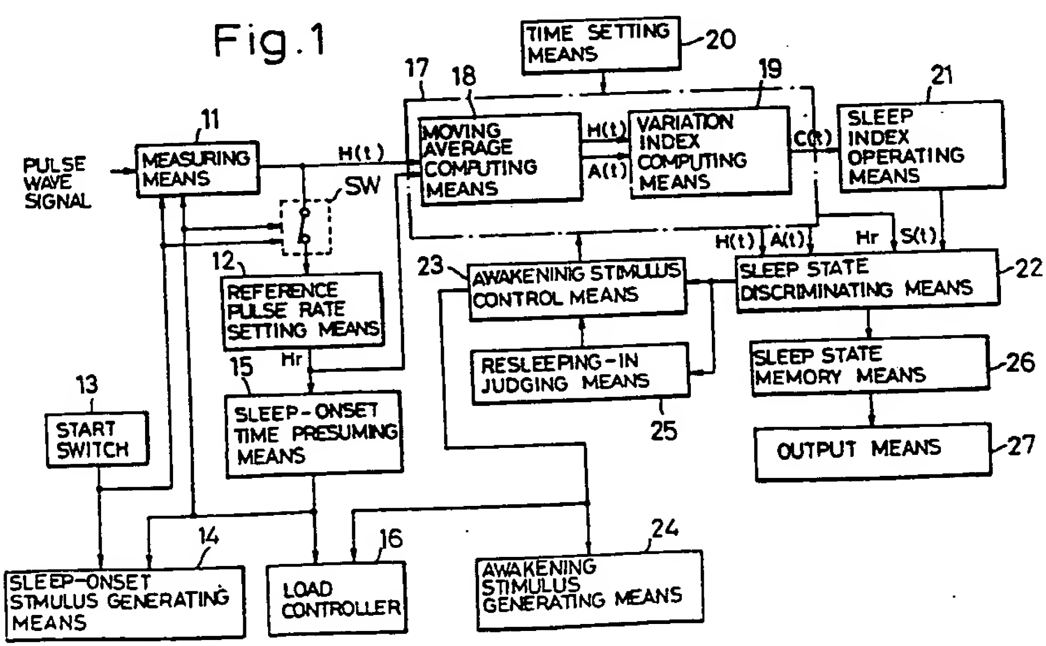

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Fig.1

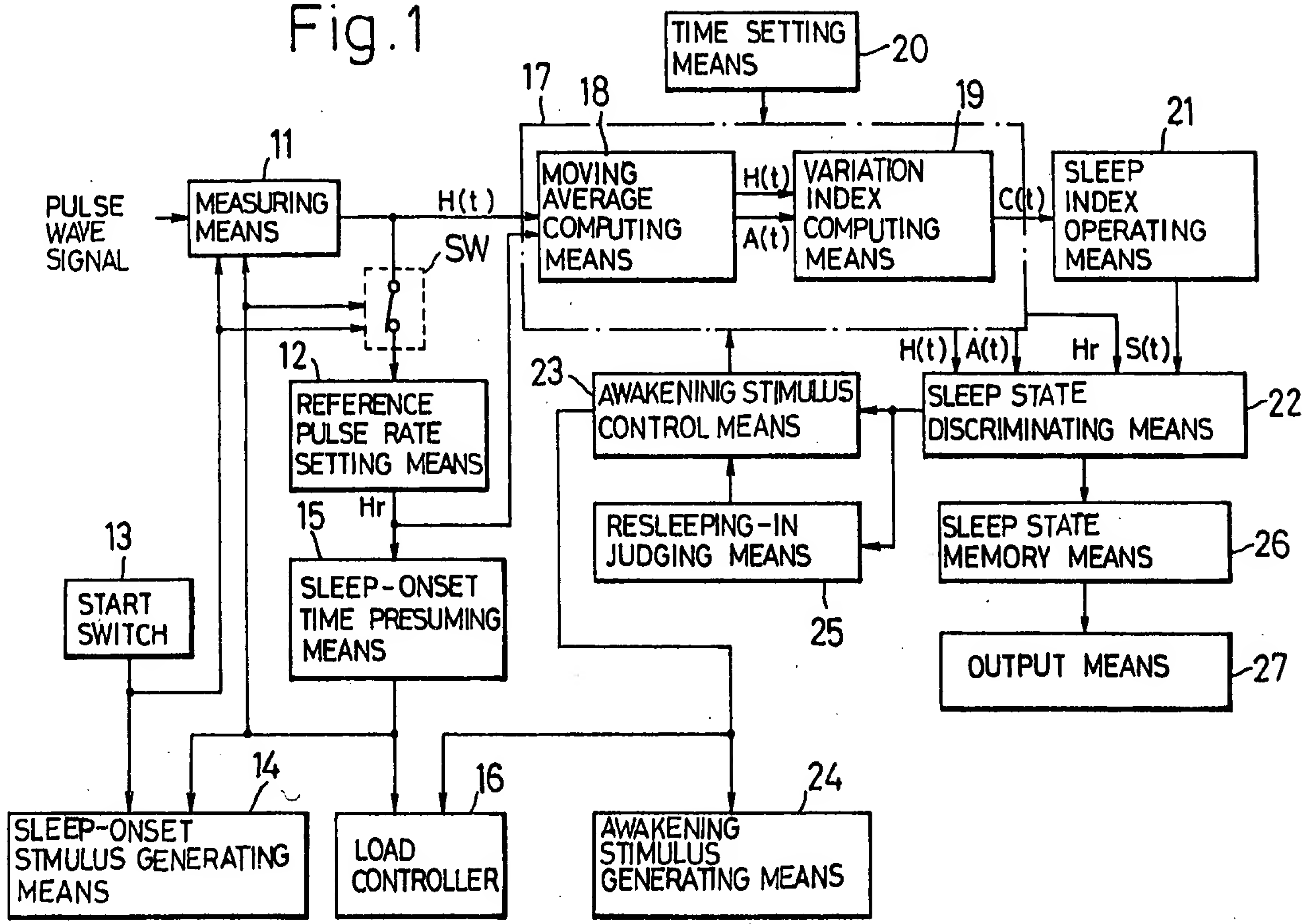
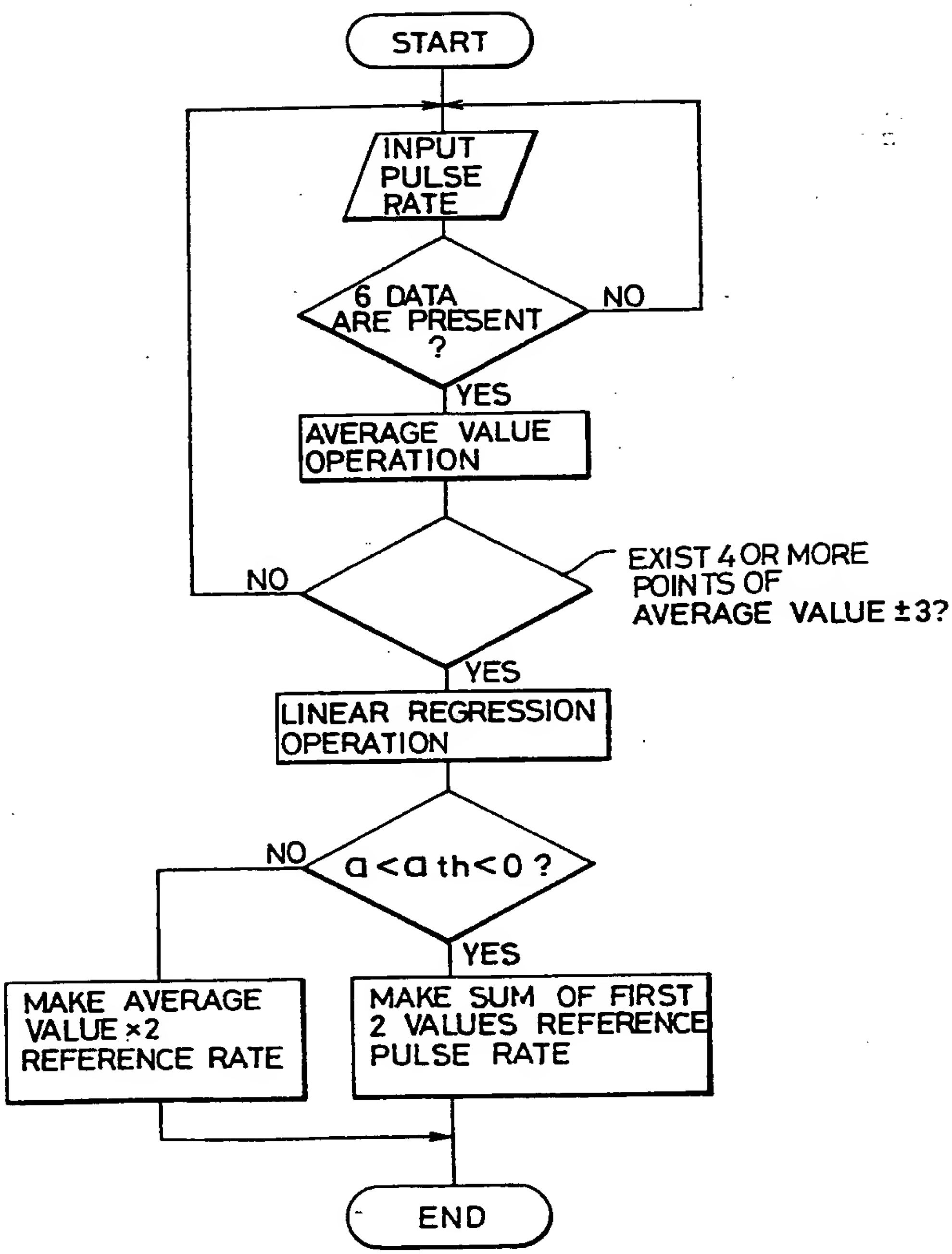
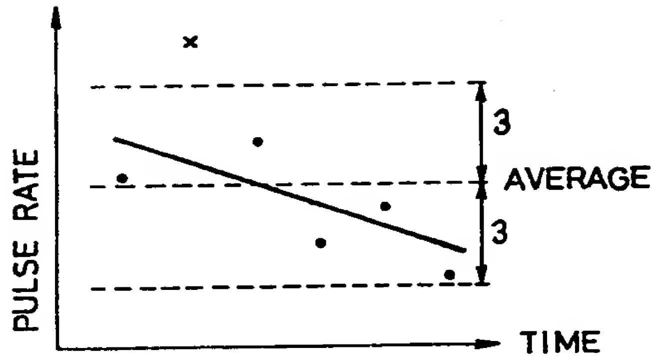

PULSE WAVE SIGNAL
MEASURING MEANS
11
H(t)
SW
12
REFERENCE PULSE RATE SETTING MEANS
Hr
15
SLEEP-ONSET TIME PRESUMING MEANS
13
START SWITCH
14
SLEEP-ONSET STIMULUS GENERATING MEANS
16
LOAD CONTROLLER
17
18
MOVING AVERAGE COMPUTING MEANS
H(t)
A(t)
19
VARIATION INDEX COMPUTING MEANS
TIME SETTING MEANS
20
C(t)
21
SLEEP INDEX OPERATING MEANS
H(t)
A(t)
Hr
S(t)
22
SLEEP STATE DISCRIMINATING MEANS
23
AWAKENINIG STIMULUS CONTROL MEANS
RESLEEPING-IN JUDGING MEANS
25
SLEEP STATE MEMORY MEANS
26
OUTPUT MEANS
27
24
AWAKENING STIMULUS GENERATING MEANS

Fig. 2



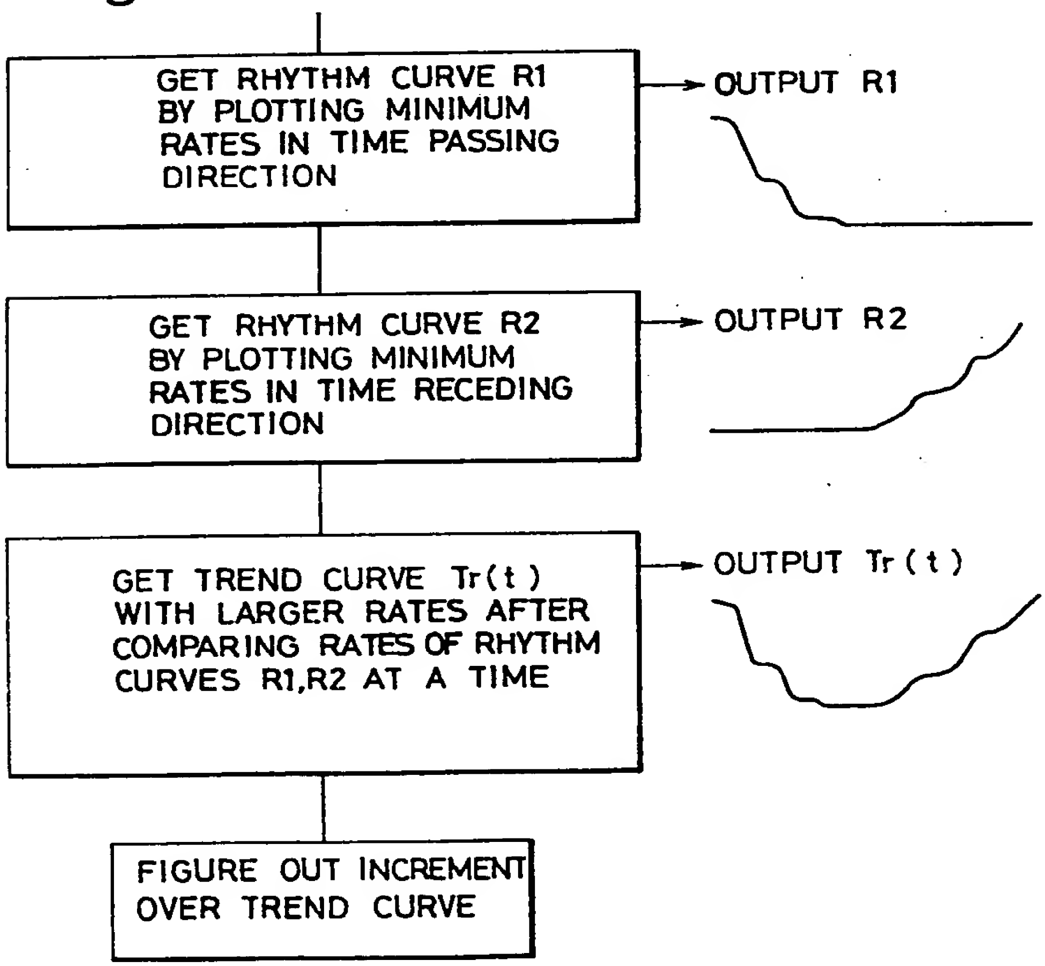
START
INPUT PULSE RATE
6 DATA ARE PRESENT ?
NO
YES
AVERAGE VALUE OPERATION
EXIST 4 OR MORE POINTS OF AVERAGE VALUE ±3?
NO
YES
LINEAR REGRESSION OPERATION
a<a th<0 ?
NO
YES
MAKE AVERAGE VALUE ×2 REFERENCE RATE
MAKE SUM OF FIRST 2 VALUES REFERENCE PULSE RATE
END

Fig. 3



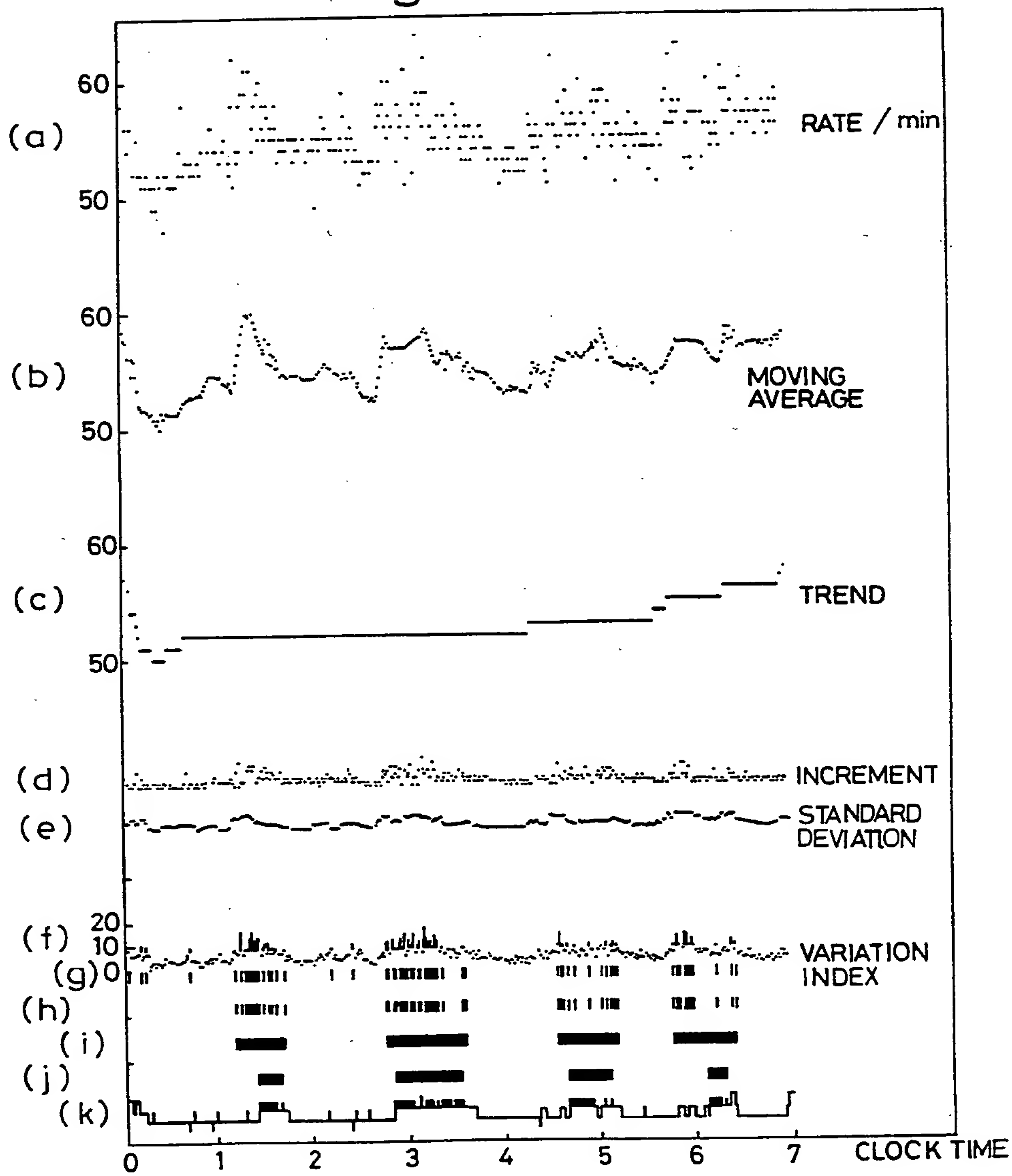
PULSE RATE
3
AVERAGE
3
TIME

Fig. 4



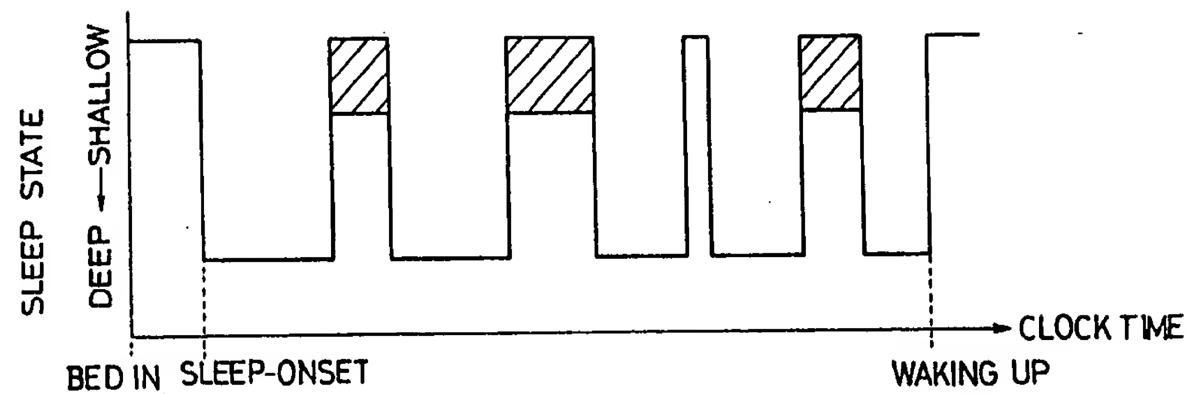
GET RHYTHM CURVE R1 BY PLOTTING MINIMUM RATES IN TIME PASSING DIRECTION
OUTPUT R1
GET RHYTHM CURVE R2 BY PLOTTING MINIMUM RATES IN TIME RECEDING DIRECTION
OUTPUT R2
GET TREND CURVE Tr(t) WITH LARGER RATES AFTER COMPARING RATES OF RHYTHM CURVES R1,R2 AT A TIME
OUTPUT Tr(t)
FIGURE OUT INCREMENT OVER TREND CURVE

Fig. 5



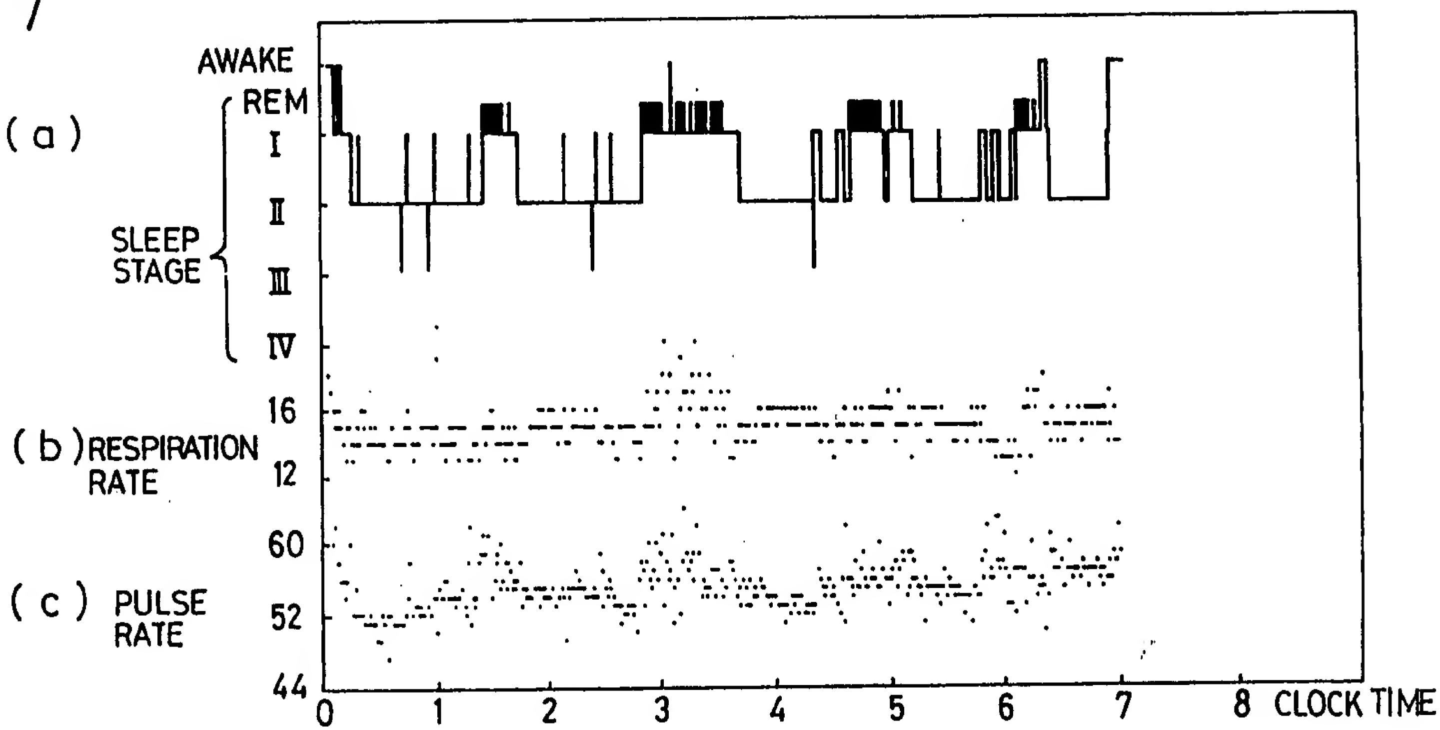
60
50
(a)
RATE / min
60
50
(b)
MOVING AVERAGE
60
50
(c)
TREND
(d)
INCREMENT
(e)
STANDARD DEVIATION
(f)
20
10
(g) 0
VARIATION INDEX
(h)
(i)
(j)
(k)
0
1
2
3
4
5
6
7
CLOCK TIME

Fig. 6



SLEEP STATE
DEEP ← SHALLOW
CLOCK TIME
BED IN
SLEEP-ONSET
WAKING UP

Fig. 7



(a)
SLEEP STAGE
AWAKE
REM
I
II
III
IV
(b) RESPIRATION RATE
16
12
(c) PULSE RATE
60
52
44
0
1
2
3
4
5
6
7
8
CLOCK TIME

"System for Discriminating Sleep State"

SPECIFICATION

TECHNICAL BACKGROUND OF THE INVENTION

This invention relates to a system which estimates the human sleep state over the entire bedtime on the basis of such biological signals as pulse rate, respiration rate and so on.

The system of the kind referred to can be effectively contributive to assurance of optimum or good quality sleep or the like purpose through a discrimination of the sleep state at a preliminarily set time, a determination of optimum wake-up time in response to the discriminated sleep state and so on.

DESCRIPTION OF THE RELATED ART

It has been well known that the sleep state for every night of human bodies is generally non-uniform but a socalled REM/NREM cycle of rapid eye movement (REM) sleep and non-rapid eye movement (NREM) sleep is repeated for several times periodically at a cycle of 80 to 120 minutes, and that, in normal sleep, each such cycle involves a change of sleep state so that a relatively shallow sleep state shifts to a relatively deep sleep state, then the shallow sleep state appears again after a continuation of the deep sleep state and thereafter the REM sleep appears. Here, the REM sleep represents a period in which the sleep has different characteristics with respect to that in the NREM sleep, and is regarded to be the state after which can smoothly shift to awakening

state so long as the human is in natural sleep. In other words, it is considered optimum that the human wakes up in several minutes immediately after the REM sleep, i.e., in an awakening period.

In recent days, there have been suggested various attempts of attaining comfortable awakening state with the foregoing variation in the sleep utilized. For example, Japanese Patent Application Laid-Open Publication No. 63-205592 of H. Masaki discloses an alarm clock which obtains as data a required time for the pulse rate to reach a certain unit number for subjecting the data always to an analysis so as to discriminate the REM sleep appearing in the change of sleep state and for obtaining the awakening state by means of a proper alarm signal generated upon the discrimination of the REM sleep. According to this alarm clock, the awakening signal can be prevented from being generated during the NREM sleep, so as to avoid that the worst awakening is provided to a user by forcibly waking up the user with the alarm signal generated while the user is in the relatively deep sleep state of the NREM sleep. Since it is considered, however, that an abrupt waking-up even during the REM sleep may still cause the user to feel uncomfortable and the clock of H. Masaki only reaches the discrimination of the REM sleep from the NREM sleep, there is still remained a problem in providing the highly comfortable awakening, most probably due to that a highly precise state of the sleeping has not been able to be discriminated.

U.S. Patent No. 4,228,806 of D. Lidow also discloses a wake-up alarm device which discriminates the shallow sleep from the deep sleep with the electroencephalogram (EEG) activity and pulse rate and so on measured so as to have an alarm signal generated during the shallow sleep. In practice, however, the alarm signal generation in this known device is also made to take place in the REM sleep, and substantially the same problem as in the foregoing alarm clock by Masaki should be left unsolved. Yet, the arrangement of this known device by Lidow in which the EEG is employed for discriminating the sleep state of the user inherently requires that EEG sensor electrodes are placed on the user's head so that, while the discrimination may be improved in the accuracy, there arise such drawbacks that the use of the device is rather annoying to the user enough for rendering the device to be not suitable for private or home use except for the use in hospitals for treatment of sleep disorders, and that required arrangement for the EEG measuring and data processing for the intended discrimination renders the device to be large in size and rather expensive.

In Japanese Patent Application Laid-Open Publications No. 63-19161 of I. Mihara et al, No. 63-82673 of K. Araki et al and No. 63-150047 of M. Kitado et al, further, there have been suggested various measures for achieving smooth awakening and a help to fall asleep by means of the pulse rate measurement or EEG analysis.

In any one of these publications, however, there still

has been suggested no data for providing effective information to be contributive to a comfortable awakening by reliably estimating the NREM and REM sleeps with such biological signals as the pulse rate which can be obtained in simpler and easier manner, while the biological signal may also be the respiration rate, body temperature which may be made employable by measuring emitted ultrared rays from the human body, and so on.

FIELD OF TECHNOLOGY

A primary object of the present invention is, therefore, to provide a system for discriminating highly precisely the sleep state, in particular, the REM and NREM sleeps with a simpler and inexpensive arrangement that can prepare required information for the discrimination on the basis of such easily available biological signal as the pulse rate, and for being sufficiently contributive to a transmission of the information capable of providing a comfortable awakening.

According to the present invention, this object can be realized by a system for discriminating the sleep state, wherein an easily available signal of human body per unit time set by a measuring time setting means is measured by a measuring means to obtain a biological signal, a variation in the biological signal is computed by a variation computing means, and the NREM sleep and any other sleeps are discriminated by a sleep state discriminating means on the basis of the variation in the biological signal, characterized in that the variation

computing means provides a variation indexes denoting variation tendency of the biological signal on the basis of first variation amount showing a tendency of increment in time series of measured value of the biological signal from a starting time of the measurement, and the sleep state discriminating means discriminates the states of the sleep on the basis of distribution density of the variation indexes which exceed a predetermined threshold.

Other objects and advantages of the present invention shall be made clear in following description of the invention detailed with reference to an embodiment of the invention shown in accompanying drawings.

BRIEF EXPLANATION OF THE DRAWINGS

FIGURE 1 is a block diagram showing the system for discriminating the sleep state according to the present invention;

FIG. 2 is a flow chart of the operation at a means for setting a reference pulse rate in the system of FIG. 1;

FIG. 3 is a diagram for carrying out a regression analysis in the system of FIG. 1;

FIG. 4 is a flow chart showing a part of an operation at a variation index computing means in the system of FIG. 1;

FIG. 5 is a diagram for the discrimination of the sleep state in the system of FIG. 1;

FIG. 6 is a diagram showing an example of the sleep state discriminated in the system of FIG. 1; and

FIG. 7 is a diagram showing changes of the biological

signals and the sleep state.

While the present invention shall now be explained with reference to the embodiment shown in the following drawings, it will be readily appreciated that the intention is not to limit the invention only to the embodiment shown, but rather to include all alteration, modifications and equivalent arrangements possible within the scope of appended claims.

DISCLOSURE OF PREFERRED EMBODIMENT

Referring here to FIG. 1 showing the system for discriminating the sleep state according to the present invention, a measuring means 11 receives as an input a pulse wave signal from a pulse wave sensor (not shown). For this pulse wave sensor, for example, a photosensor which detects variation in blood flow at a finger tip, ear lobe or the like portion as a variation in the light reflectance or transmission property may be employed, and its detection signal is to be transmitted by means of a wire transmission or wireless transmission through a frequency modulation to the measuring means 11, where a pulse curve of the received signals is shaped into a pulse wave and a value of count for every unit time is provided thereout as output data. While the unit time is mainly set to be one minute, the data for every 30 seconds as a unit time are employed by the time when the user is presumed to begin to sleep. The thus obtained pulse rate H(t) includes certain noise component due to body movement or the like but may be deemed employable without hindrance

to obtain the trend of variation in the pulse rate.

The pulse rate H(t) is provided through a switching element SW into a reference pulse rate setting means 12 forming a reference value setting section. The switching element SW is controlled by a start signal provided upon operation of a start switch 13 and the switching element SW is set to be ON state by operating the start switch 13 when the measurement is to be started. The start signal is also provided to the measuring means 11 and to means 14 for generating a stimulus for helping the user to fall asleep. At the measuring means 11, the unit time is set to be 30 seconds, and the stimulus generating means 14 operates to give the stimulus proper for helping the user to start feeling sleepy and falling asleep. That is, the stimulus generating means is arranged to generate such stimulus effective to promote the user's shift to the state of asleep as a sound stimulus of a slow and sleepy music that fades out in several minutes, an aromatic stimulus containing a component considered effective for sedative action (such as a fragrance of lavender), vibratory stimulus, optical stimulus or the like alone or in combination.

The reference pulse-rate setting means 12 carries out such a processing as shown in a flow-chart of FIG. 2 to remove any noise, i.e., an artifact, and determines a reference pulse rate Hr which can be regarded as a pulse rate during resting and awakening state from the bedrest time to the sleep-onset time, as a reference value.

Therefore, in the reference pulse-rate setting means 12, six of the pulse rate H(t) provided out of the measuring means 11, that is, its outputs for every 3 minutes are operated in one lump so that, when a state in which more than four points of less than ±3 with respect to an average value for the six pulse rate values are present, it is discriminated that the user is in a resting state having less variation in the pulse rate, and a regression operation is carried out with remaining values after removal of the values exceeding ±3 with respect to the average value (see FIG. 3), that is, a regression line representing a trend of variation in the pulse rate H(t) with respect to the time elapsed, by means of the linear regression analysis. When a regression coefficient a denoting the slope of the regression line satisfies a condition $a<a\text{-}th<0$ wherein a-th is a set negative threshold, it is discriminated that the pulse rate H(t) is decreasing, and a sum of first two of the values below ±3 with respect to the foregoing average value of the data subjected to the regression operation is made to be the reference pulse rate Hr. When the above condition is not satisfied, a value obtained by multiplying the foregoing average value by 2 is made to be the reference pulse rate Hr. In this way, the reference pulse rate Hr is determined as a pulse rate per one minute at a time when less variation is acknowledged in the pulse rate H(t) sequences. That is, the reference pulse rate Hr is to be set at a time point where the pulse rate H(t) has become

stable as based on a knowledge that the pulse rate H(t) is stabilized during the resting and awakening state.

The reference pulse rate Hr thus corresponding to the pulse rate during the resting and awakening state and provided out of the reference pulse-rate setting means 12 is provided to a sleep-onset time presuming means 15, where a value of 80 to 95%, for example, its 93% of the reference pulse rate Hr is set as a threshold. In the sleep-onset time presuming means 15, thereafter, the pulse rate H(t) signals are subjected to the same processing as in the reference pulse-rate setting means 12 to discriminate whether or not the pulse rate H(t) is in the decreasing period so that, in an event where the pulse rate H(t) detected during the decreasing period becomes below the threshold, it is discriminated that the user has started to sleep at this moment, and the means 15 provides a sleep-onset signal. The switching element SW is turned OFF when this sleep-onset signal is generated, and the unit time for counting the pulse rate at the measuring means 11 is altered from 30 seconds to 1 minute. The sleep-onset signal stops the operation of the sleep-onset stimulus generating means 14 and also turns a load control means 16 OFF. This load control means 16 is operated for ON and OFF controlling of an external load and is before sleep set in ON state but is turned OFF upon receipt of the sleep-onset signal, whereby any of TV receiving set, luminair and the like electric devices employed as the external load can be prevented from being left not turned

off to disturb the user's sleep.

The pulse rate H(t) and the reference pulse rate Hr obtained as in the foregoing are provided into a variation index operating means 17, which comprises a moving average computing means 18 and a variation index computing means 19, the former obtaining a moving average A(t) of the pulse rate H(t) and the latter obtaining a variation index C(t) on the basis of the pulse rate H(t) and moving average A(t). In the present instance, the moving average computing means 18 stores the pulse rates H(t) per 1 minute as received from the measuring means 11 and sequentially computes the moving average with a time interval of τ minutes (τ=5, for example) set before and after respective time points. That is, when the computation is carried out in real time, a moving average at a time τ minutes before the time point of the computation. Since the pulse rates H(t) for every 30 seconds are provided out of the measuring means 11 prior to the generation of the sleep-onset signal, the variation index computing means 19 carries out an addition of every two of the pulse rates H(t) until the generation of the sleep-onset signal to thereby obtain the pulse rate H(t) per every unit of time.

In respect of central value for computing the moving average, differences from all other values within a range to which the moving average is computing are taken and, when the number of the values the difference of which exceeds a predetermined threshold ε (ε=3, for example) is

more than 70% of the number of the values within the range for computing the moving average, the value is removed representing as an abnormal value. That is, when any abnormal value is present during computing the moving average, the average value from which any abnormal value is removed is to be employed as the moving average, whereby any influence on the moving average of noise component in an event where the average value varies abruptly due to the user's body movement or the like can be removed. Further, when the value at the time when the moving average is obtained is an abnormal value, a linear interpolation between a pair of non-abnormal values which are the closest before and after the particular time is carried out and the moving average is replaced by this value obtained through the linear interpolation. The moving average cannot be obtained for a period of 2τ minutes from the starting time and, during this period, the moving average values are computed approximatively where the reference pulse rate Hr provided out of the reference pulse rate setting means 12 is defined as an initial value of the moving average.

On the other hand, the system is so arranged as to be able to discriminate the sleep state at fixed time intervals from the starting time to the wake-up time, depending on the manner in which the time setting means 20 is set, and the system in the present instance is started by the operation of the start switch 13 as has been partly referred to, upon which the wake-up time measuring point

is preliminarily set by a time setting means 20. In the present instance, the measurement of the sleep state from the starting time is carried out at least once during the user's sleep period and, provided that the intended wake-up time is made Tw and the discrimination time interval is made Ti, then the sleep state is to be discriminated at a measuring time

$$tn = Tw-n \cdot Ti \quad (n=1,2 \ldots N)$$

In other words, the discrimination of the sleep state is to be started in ahead by a time n•Ti with respect to the set wake-up time Tw. The time interval Ti is set to be an integer multiple of a unit time set by the measuring means 11, and the smallest unit will be 1 minute, i.e., the unit time. At every discriminating time tn, the computation at the variation index computing means 19 is carried out with the pulse rate H(t) and moving averages A(t) obtained from the starting time to the discriminating time tn, and the discrimination of the sleep state is carried out as in the following references.

More specifically, also with reference to FIGS. 4 and 5, the variation index computing means 19 obtains first a trend line Tr(t) denoting a trend of the temporal change of the H(t) sequences on the basis of the moving average A(t). This trend line Tr(t) is the one obtained in such that a first rhythm curve R1 is obtained with the minimum values of the moving average at every predetermined unit time in respect of passing direction of time, a second rhythm curve R2 is obtained with the minimum values of the

moving average at every predetermined unit time in respect of receding direction of time and the larger value between the first and second rhythm curves R1 and R2 at each time is plotted as a point of the line Tr(t). Then the obtained trend line Tr(t) is compared with the pulse rates H(t) provided out of the measuring means 11, in respect of the size, and an increment I(t) of the pulse rate H(t) with respect to the trend line Tr(t) is represented as in a following expression:

$$I(t)=H(t)-Tr(t) \quad \ldots \text{ when } H(t) \geqq Tr(t), \text{ and}$$

$$I(t)=0 \quad \ldots \text{ when } H(t)<Tr(t).$$

Further, the mean square root D(t) of a difference of the pulse rate H(t) from the moving average A(t) within a range of τ minutes before and after the respective time t (i.e., a standard deviation in such range) is obtained in a manner of following expression:

$$D(t)=[\Sigma\{H(t+j)-A(t)\}^2/(2\tau+1)]^{1/2}$$

where $[j=-\tau, \tau]$ and $0 \leqq t+j \leqq tn$. The variation index C(t) is obtained as (a) linear combination of the obtained increment I(t) and standard deviation D(t) as in a following expression:

$$C(t)=a1 \cdot I(t)+a2 \cdot D(t)$$

Since, the increment I(t) shows a larger difference between individuals than the standard deviation D(t), both weight a1 and a2 are so set as to satisfy a condition a1<a2. An output attained with a1=1 and a2=2 for example is shown by a graph (f) in FIG. 5, in which graphs (a)-(e) represent the pulse rate H(t), moving average A(t), trend

line Tr(t) and standard deviation D(t), respectively. In this case, the pulse rate H(t) shows smaller temporal variation in the NREM sleep so that the variation index C(t) (graph (f) in FIG. 5) will also be small, while the pulse rate H(t) is larger in the REM sleep or awakening state so that the variation index C(t) will also be larger. In other words, the variation index C(t) is an index into which the increment and decrement and the temporal variation as well are combined, and the NREM and REM sleeps can be discriminated from each other in accordance with the magnitude of the variation index C(t).

Therefore, the variation index C(t) is compared with a threshold Cth set in a sleep index operating means 21. That is, a sleep index S(t) is set by means of the magnitude of the variation index C(t) with respect to the threshold Cth, upon which the sleep index S(t) is defined as in a following expression:

$S(t)=1$ ... when $C(t)\geq Cth$, and

$S(t)=0$ ... when $C(t)<Cth$.

Here, the threshold Cth is so set that the variation indexes C(t) are sequentially arranged from the largest one to the smallest one and 20% of the upper larger ones will be S(t)=1. In other words, S(t)=1 is assigned to the upper 20% of the variation indexes C(t), while S(t)=0 is assigned to the lower 80%. Such setting of the threshold Cth is based on a knowledge that, as in the foregoings, the variation indexes C(t) correspond to the sleep state in such that the period showing the larger variation

indexes C(t) corresponds to the REM sleep, and that the REM sleep occupies about 20% of the entire sleep period in normal sleep in the night time.

The sleep indexes S(t) obtained in the foregoing manner are distributed, for example, as in graph (g) of FIG. 5, in which the points of S(t)=1 are shown by black lines, and the FIG. 5 shows that the period of higher distribution density of the black lines of S(t)=1 corresponds to the appearance of the REM sleep and awakening periods. That is, whether the user is in the NREM sleep period, the REM sleep period or in the awakening period is discriminated in a following manner. First, respective points where S(t)=1 are sequentially reviewed in the passing direction of time, intervals of k minutes are set before and after each of such points, the points of S(t)=1 but present only less than m points representing S(t)=1 in such sections are regarded to be isolated points, and they are made to be of a value 0 (graph (h) in FIG. 5). In respect of the remaining set of points, all points of S(t)=0 but present to be less than n between adjacent pair of the points of S(t)=1 are made to be of a value 1. Here, an output example of the sleep index operating means 21 when it is set that k=15, m=3 and n=15 is shown in graph (i) of FIG. 5. Through such processing, continuous black line portions are obtained and such portions are discriminated to be periods in which both the REM sleep and awakening are included.

The pulse rate H(t), reference pulse rate Hr, moving

average A(t) and sleep index S(t) which have been obtained in the foregoing manner are provided into a sleep state discriminating means 22, where the sleep states from the starting point to the measuring time tn will be classified on the basis of the sleep index S(t) provided as an output from the sleep index operating means 21, in which a period showing the sleep index S(t) of 0 is discriminated as NREM sleep period and, in a period where St=1, the pulse rate H(t) or the moving average A(t) within this period is compared with the reference pulse rate Hr and, when the reference pulse rate Hr is larger than more than one half of the values in the particular period, the same is discriminated to be

the one of the REM sleep but to be of the awakening when the reference pulse rate Hr is smaller. The sleep index S(t) is made to be 1 for the REM sleep period, and to be 2 in the awakening period. Further, a period within a predetermined time T_R after the termination of the REM sleep period (for example, 10 minutes) is regarded as an immediately after REM sleep period. Through these processings, the period of the sleep index S(t) as provided from the sleep index operating means 21 is classified to be the REM sleep (S(t)=1) and awakening periods (S(t)1=2), while the periods of S(t)=0 are to be an immediately after REM sleep period and NREM period.

A comparison of the result of discrimination of the sleep state on the basis of the pulse rate as obtained in accordance with the foregoing procedure with a result of

visual scoring by means of polysomnograph has proved that they are consistent with each other at a rate of more than 85%, which may be regarded as being considerably high in the consistency in view of the fact that even visual scoring by a plurality of specialized doctors in the particular field by means of the polysomnograph reaches only about 90%, and thus the system according to the present invention should be high in the utility.

At an awakening stimulus control means 23, the time or intensity of an awakening stimulus to be given to the user is set on the basis of the sleep state sequences. That is, provided that n=N, N-1, ... 1 in the foregoing measuring time Tn (=Tw-n·Ti), N·Ti is the maximum allowance for advancing the awakening time, and the sleep state is measured at every time interval Ti after the time Tw-N·Ti (=Tp). Provided here that the unit time for computing the pulse rate H(t) in the measuring means 11 during the sleep is Tu (1 minute in the foregoing example), it is set that $Tu \leqq Ti \leqq T_R$. Conducting the discrimination of the sleep state at every time interval Ti between the time Tp and the time Tw, it is possible to attain a result among such three different situations that the REM sleep period has terminated and shifted to the immediately after REM sleep period, that the REM sleep period has not shifted to the immediately after REM sleep period, and that the awakening period has already been reached.

Upon discrimination of the termination of the REM

sleep period, an awakening signal is generated upon termination of the REM sleep period to drive an awakening stimulus generating means 24. For the awakening stimulus, there may be employed a sound stimulus, aromatic stimulus of mint series fragrance or the like known to have awakening effect, optical stimulus, and vibratory stimulus, respectively alone or in combination. When the sound or optical stimulus is employed, it is preferable to have the level of stimulus gradually increased, but the initial sound stimulus may be set relatively lower since the sound stimulus has higher awakening effect in the immediately after REM period.

Upon discrimination of the awakening period, the provision of the awakening stimulus either before or just at the set time Tw, the timing of which is made selectable, and it is preferable that the system allows the user to perform this selection upon time setting with the time setting means 20. Further, it is considered that, in the awakening stimuli, the sound stimulus is a strong one having relatively high effect while the optical or aromatic stimulus is a weak one. It is also effective, therefore, to provide the weak stimulus increasing from the time Tp and thereafter the strong stimulus at an optimum time for giving the awakening stimulus, that is, in two steps. This will make it possible to provide to the user an excellently comfortable awakening feeling when, in particular, the immediately after REM sleep period has not been reached between the time Tp and the

time Tw, in which event the increasing weak stimulus is given in the NREM and REM sleep periods and the strong stimulus is given when the time Tw is reached, so that the sleep will be gradually led to be shallower and then the comfortable awakening can be realized.

It may be possible, on the other hand, that the user falls asleep again even after the awakening stimulus is given. The present system is provided, therefore, with a resleep judging means 25, so as to judge whether or not the user is falling asleep again. That is, the resleeping judging means 25 carries out the same processing as in the sleep-onset time presuming means 15, so that an event where the pulse rate H(t) shows a decreasing tendency or an average pulse rate for a predetermined period of time becomes smaller than the reference pulse rate will be judged to be falling asleep again. When such state is judged to be present, the awakening stimulus generating means 24 is continuously or intermittently actuated to provide the strong stimulus so as to have the awakening state reached reliably.

Further, the sleep index S(t) obtained at the sleep state discriminating means 22 is stored at a sleep state memory means 26 to which such output means 27 as a display, printer or the like device is connected. After the waking-up, therefore, the user can be furnished by the output means 27 with such a sort of sleeping diagram as shown in FIG. 6. It may also be possible to employ a voice output device for the output means 27 to have the

stored data audibly announced.

While in the foregoing embodiment an example of employing the pulse rate easily available has been referred to, it is likewise possible to employ the respiration rate as the biological signal since, as will be clear when FIG. 7 is referred to, the respiration rate shown by graph (b) and the pulse rate shown by graph (c) in FIG. 7 change in the same manner in respect of the sleep state.

What is claimed is:

1. A system for discriminating a sleep state, the system comprising means for setting a measuring time, means for measuring an easily available human body signal per unit time as a biological signal of a user for respective time, a variation index computing means providing variation indexes representing variation of the biological signal on the basis of first variation amount denoting a tendency of increment in time series of said biological signal from a starting time of the measuring to a time when the biological signal is obtained as well as second variation amount denoting the temporal variation of the biological signal, and a sleep index operating means providing sleep indexes allowing a NREM sleep state and all other sleep state discriminated from one another on the basis of distribution density of said variation indexes exceeding a predetermined threshold.

2. A system according to claim 1, which further comprises means for setting a reference value which can be regarded as said biological signal at a resting and awakening state on the basis of the biological signal at initial stage of the measurement, and means for presuming a time when the biological signal becomes below a predetermined threshold set on the basis of said reference value to be a sleep-onset time.

3. A system according to claim 2, which further comprises a sleep state discriminating means which discriminates, when said sleep index denotes other period

than said NREM sleep period, a state in which either the biological signal or a moving average value of the biological signal is above a reference value with respect to a set of measurements above a rate in a predetermined time section to be an awakening period, and any other state to be a REM sleep period.

4. A system according to claim 1, wherein the variation index computing means is provided to obtain a trend line denoting a trend of the variation with time elapsing on the basis of the moving average, and this trend line is the one obtained in such that a first rhythm curve is obtained with the minimum values of the moving average at every unit time in respect of passing direction of time, a second rhythm curve is obtained with the minimum values of the moving average at every unit time in respect of receding direction of time and the larger value between the first and second rhythm curves at each time is plotted as a point of the trend line.

5. A system according to claim 3, which further comprises means for generating an awakening stimulus to be given to the user, means for setting an awakening time, and means for controlling operation of said awakening stimulus generating means.

6. A system according to claim 5, which further comprises means for judging a state of resleeping on the basis of said biological signal measured after an actuation of said awakening stimulus generating means and actuating again the awakening stimulus generating means.

7. A system for discriminating a sleep state substantially as hereinbefore described with reference to and as shown in the accompanying drawings.